Continuous Non-Invasive Measurement of CBF, $CMRO_2$ and OEF in Critically Ill Brain-Injured Patients

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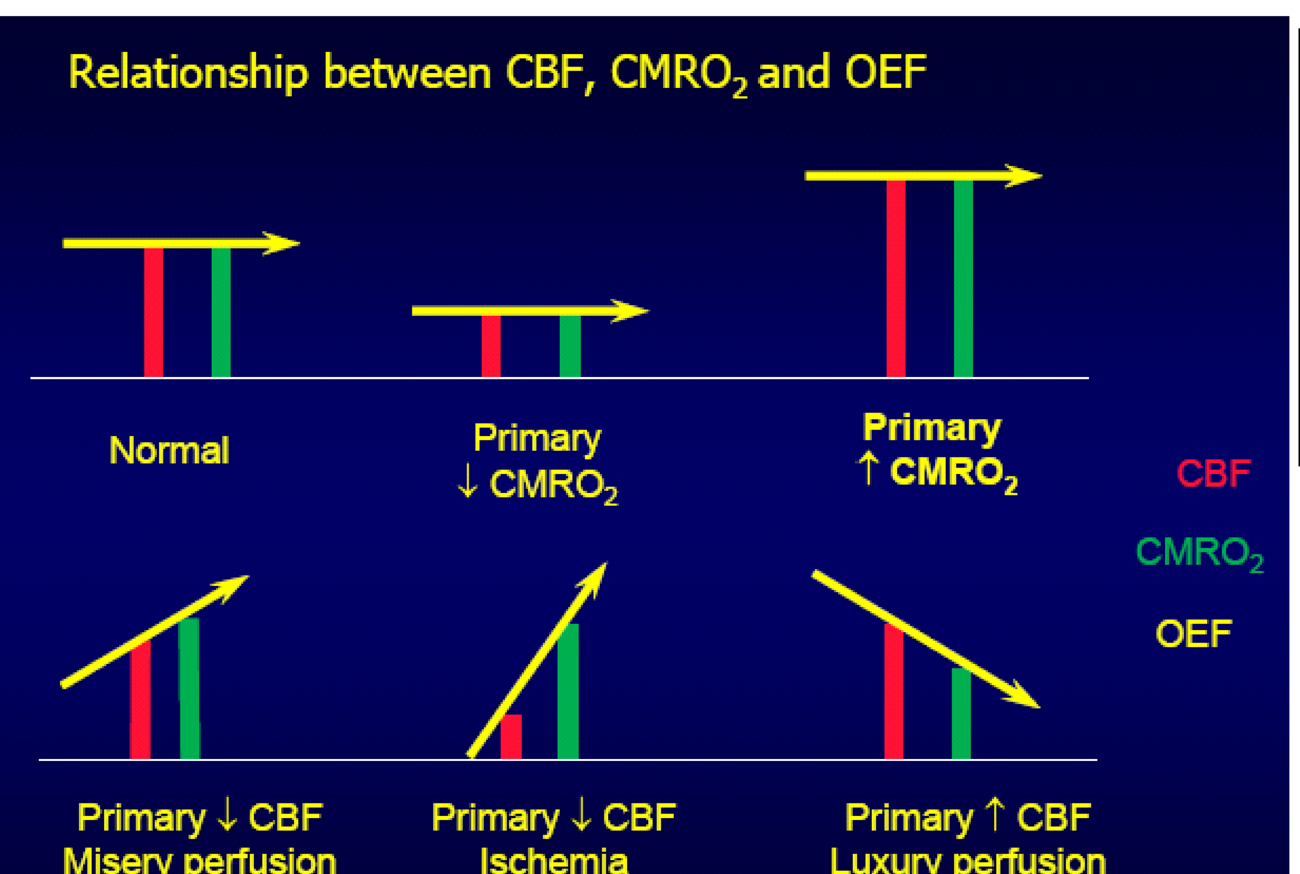
Introduction

- **The focus of neurocritical care is to prevent secondary brain injury**
- **Our ability to monitor and treat secondary injury remains poor**
  - **Generalized guidelines may not apply to specific patients**
  - **Invasive monitors examine the local environment and are not suitable for most patients**
  - **Imaging studies require transporting potentially unstable patients and are not monitors (non-continuous)**
  - **A non-invasive, real-time, bedside monitor of cerebral ischemia would potentially be of great utility in the management of brain injured patients**

Brain injury occurs when CBF does not match metabolic demands

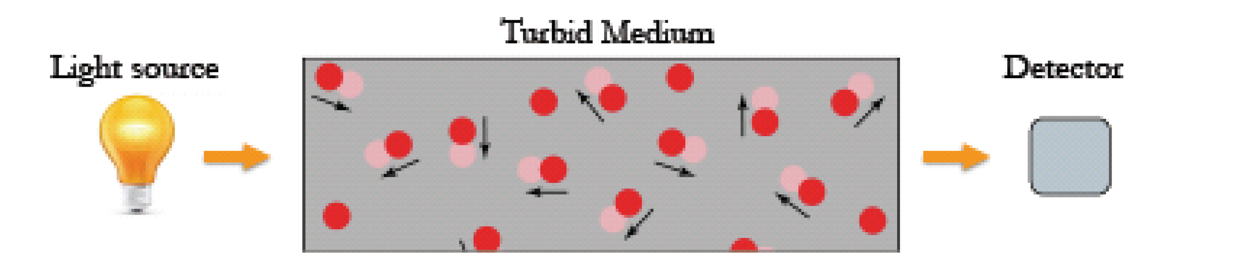


Diringer etal Neurosurg. 2000;92:7-13

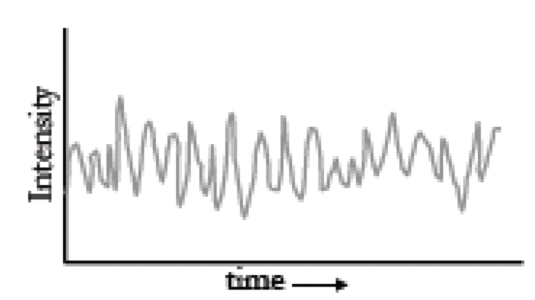
Goal: We explored the potential utility of a non-invasive monitor of relative changes in CBF, CMRO2, and OEF in a group of NeuroICU patients

Methods

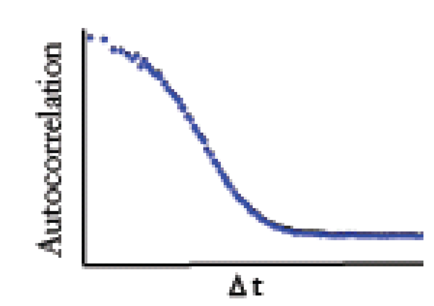
Diffuse Correlation Spectroscopy



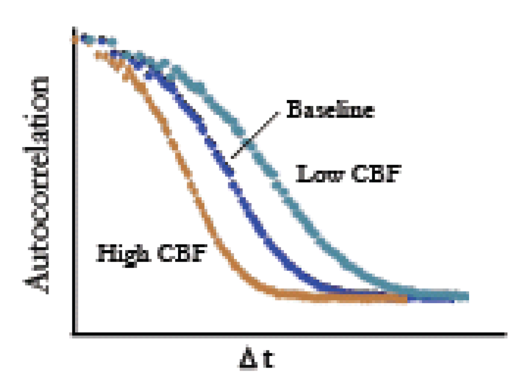
Light scattering by moving particles causes temporal fluctuations in detected light intensity



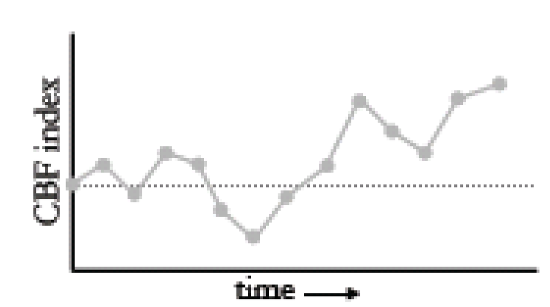
Autocorrelation of intensity fluctuations measures the coherence of scattered light



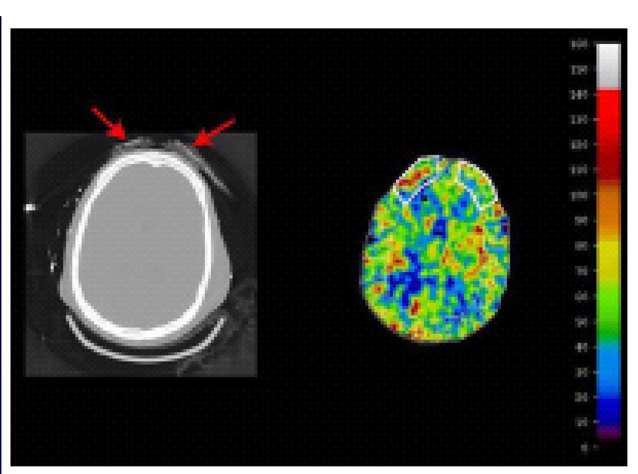
The coherence of scattered light changes with RBC velocity

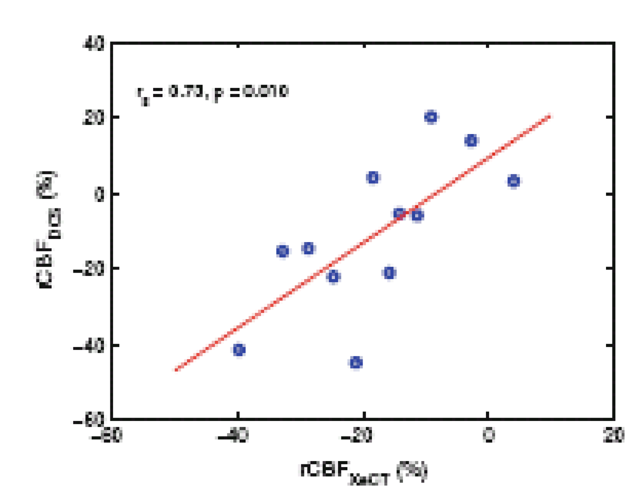


Which allows calculation of change in relative CBF over time



DCS CBF Agrees with Xe CT CBF





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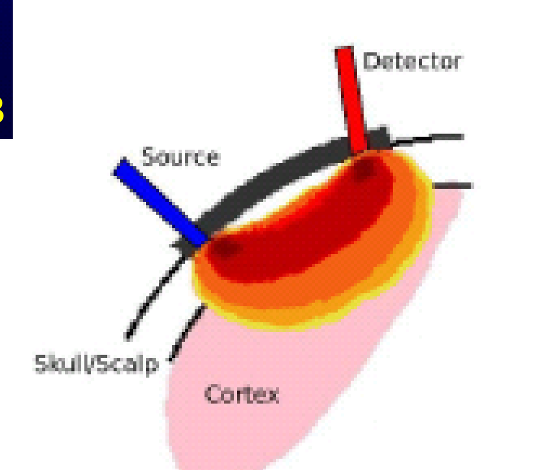
Combining DCS with NIRS to calculate OEF and $CMRO_2$



Schematic of source/detector configuration for combined DCS/NIRS measurements

$$rCMRO_2 = rOEF \times rCBF$$

rCBF measured by DCS

rOEF calculated from S_aO_2 and S_tO_2

S_tO_2 measured by NIRS

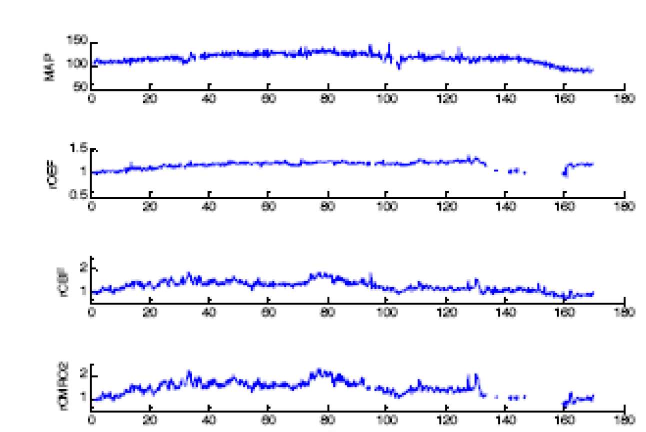
Study Design

- Single center observational study
- Inclusion criteria: patients > 18 years old admitted to NeuroICU with severe TBI, ICH, SAH
- Exclusion criteria: Age < 18, pregnant
- Subjects monitored for up to 3 hours on multiple days (between 2-7)
- rCBF, rOEF, $rCMRO_2$ over time calculated for each recording session

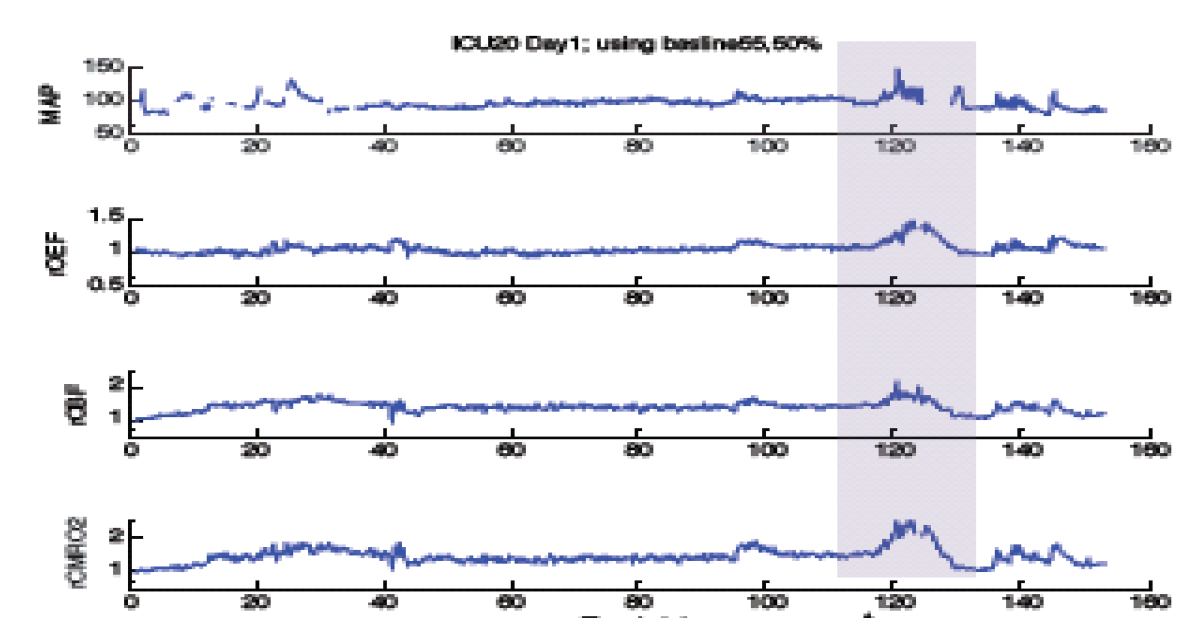
Results

Age (yr)	Gender	Race	Primary Injury Mechanism	Days Monitored
59	Female	Caucasian	SAH (Aneurysm Rupture)	7
24	Male	Black	TBI	3
71	Female	Caucasian	SAH (Aneurysm Rupture)	3
40	Male	Caucasian	SAH (Aneurysm Rupture)	3
46	Male	Caucasian	TBI	3
57	Male	Black	SAH (Aneurysm Rupture)	4
73	Female	Unknown	SAH (Aneurysm Rupture)	4
53	Female	Black	SAH (Aneurysm Rupture)	4
46	Male	Caucasian	SAH (Aneurysm Rupture)	3
58	Female	Caucasian	SAH (Aneurysm Rupture)	3
57	Female	Black	SAH (Aneurysm Rupture)	5
45	Female	Caucasian	SAH (Aneurysm Rupture)	7
19	Female	Asian	ICH (AVM Rupture)	2
43	Female	Black	SAH (Aneurysm Rupture)	3
64	Female	Black	Carotid puncture during surgery	1

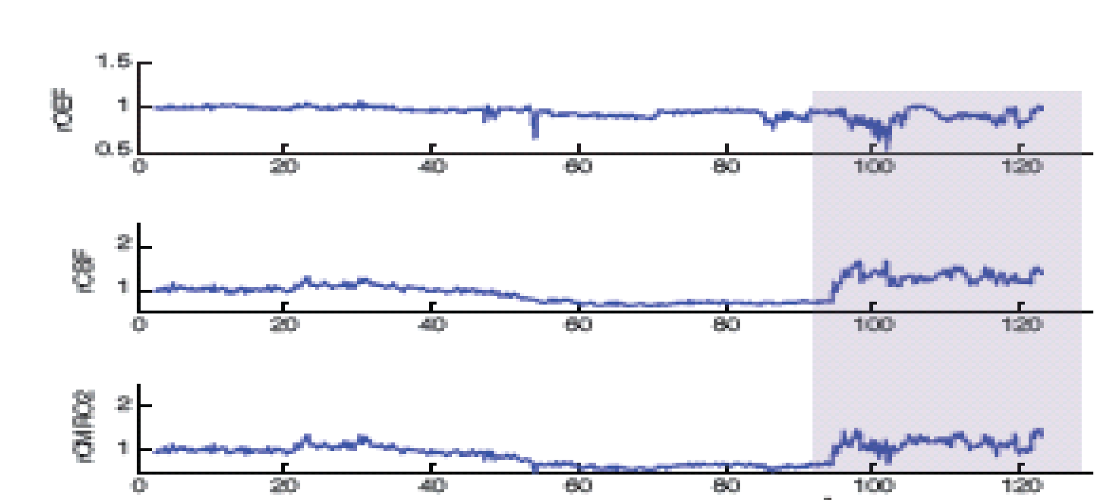
Example recording session



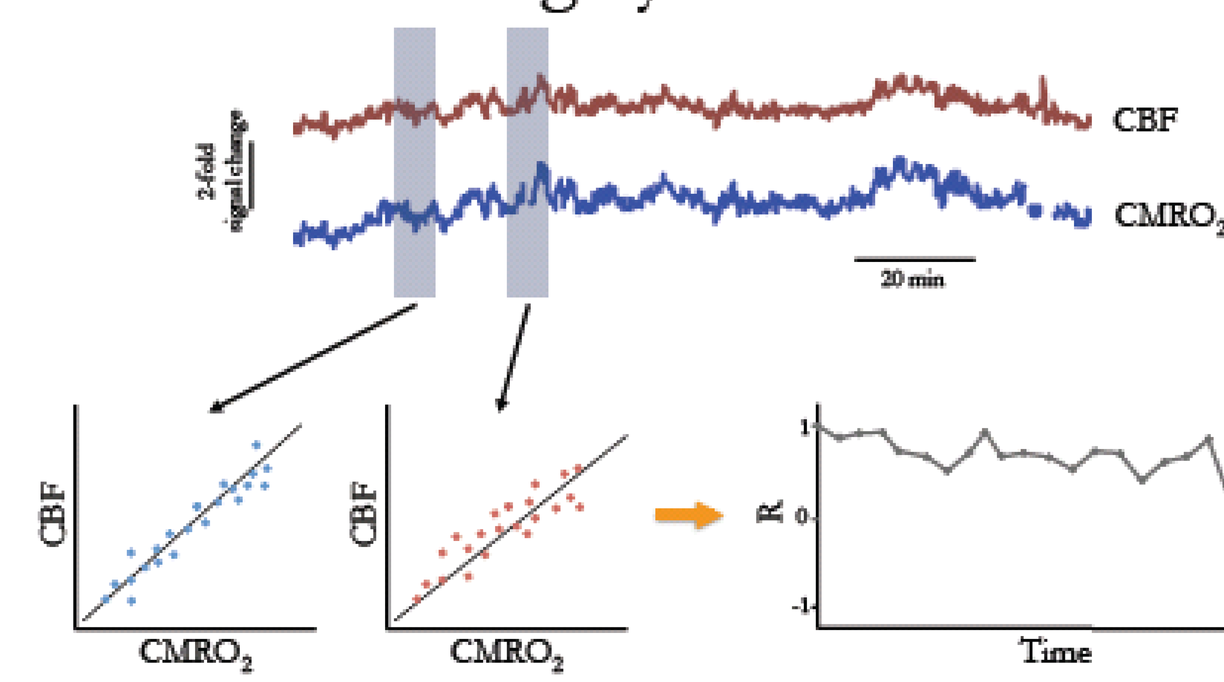
CBF/$CMRO_2$ mismatch with acute rise in OEF



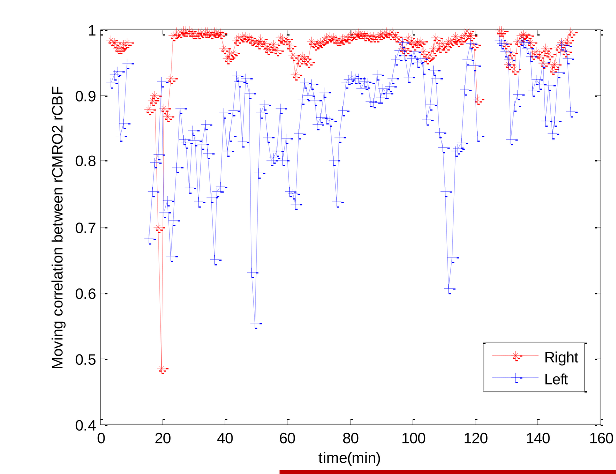
Decrease in OEF associated with increased CBF

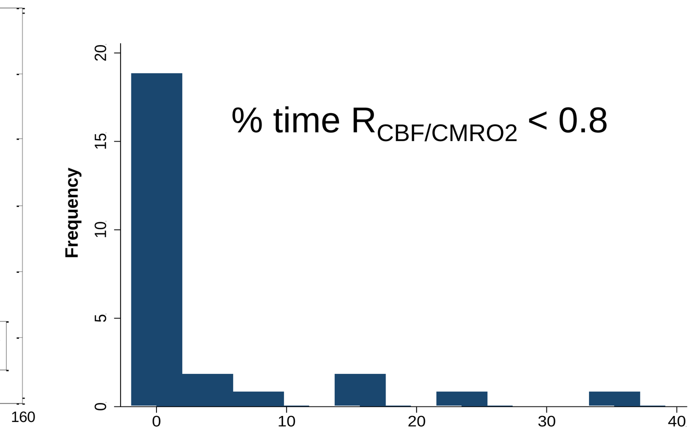


CBF and $CMRO_2$ are highly correlated



Method for constructing correlation index over time





Conclusions

- **Preliminary proof-of-concept**
  - Combining DCS with NIRS allows simultaneous measurement of relative changes in CBF,CMRO2, and OEF
- **May ID relative cerebral ischemia that could not be predicted by one parameter**
- **CMRO2 has significant short term fluctuations**
  - CBF-CMRO2 appear highly correlated
  - Suggests CBF is matched to metabolic demands
- **CMRO2 may need to be accounted for in studies investigating continuous autoregulation indices**
- Future Directions
  - *Evaluate CBF-OEF correlations*
  - *Use NIR absorbing dye(ICG) to calibrate recordings to yield absolute CBF/CMRO2(collaboration with Keith St Lawrence, U Western Ontario*
  - *Validate non-invasive absolute values with measures of CBF and ischemia(thermodil, MD, PbO2)*
- Study Limitations
  - *Sample size, single center study*
  - *Maesurement require bedside physicist*
  - *Limited recording period*
  - *Only relative changes measured*
    - ✓ *Cannot compare between subjects*
    - ✓ *Cannot tell if baseline abnormal*

- NIH 1R21NS061857